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# Koocanusa Reservoir, Lincoln County, Montana, and British Columbia, Canada

National Eutrophication Survey, Corvallis, Oreg

Prepared for
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REPORT

ON

KOOCANUSA RESERVOIR

LINCOLN COUNTY, MONTANA,

AND

BRITISH COLUMBIA, CANADA

EPA REGION VIII

WORKING PAPER NO. 795

WITH THE COOPERATION OF THE

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AND THE

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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|---|---|---|
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# FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

## OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating cost-effective and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

## ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

## LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General John J. Womack, the Adjutant General of Montana, and Project Officer Major William Younger, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

# NATIONAL EUTROPHICATION SURVEY
## STUDY LAKES AND RESERVOIRS
## STATE OF MONTANA

| LAKE NAME | COUNTY |
|---|---|
| Canyon Ferry | Broadwater, Lewis and Clark |
| Clark Canyon | Beaverhead |
| Flathead | Flathead, Lake |
| Georgetown | Deer Lodge, Granite |
| Hebgen | Gallatin |
| Koocanusa | Lincoln, MT; British Columbia, Can. |
| Mary Ronan | Lake |
| McDonald | Flathead |
| Nelson | Phillips |
| Seeley | Missoula |
| Swan | Lake |
| Tally | Flathead |
| Tiber | Liberty, Toole |
| Tongue River | Big Horn |
| Whitefish | Flathead |
| Yellowtail | Carbon, Bighorn, MT; Bighorn, WY |

KOOCANUSA RESERVOIR

KOOCANUSA RESERVOIR

STORET NO. 3006

I. CONCLUSIONS

A. Trophic Condition

Survey data indicate that Koocanusa Reservoir is mesotrophic. It ranked eleventh in overall trophic quality when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six parameters*. Eleven of the water bodies had less median total phosphorus, 14 had less median dissolved orthophosphorus, ten had less median inorganic nitrogen, six had less mean chlorophyll a, and four had greater mean Secchi disc transparency. No significant depression of dissolved oxygen occurred at depths as great as 71.6 meters.

Survey limnologists noted some surface concentrations of algae in September.

B. Rate-Limiting Nutrient:

The algal assay results indicate the reservoir was nitrogen limited in June. The reservoir data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--Koocanusa Reservoir is an international water body, and about 17% of the volume, 38% of the surface area, and 86% of the drainage area are in Canada (Bonde, 1976). Because

* See Appendix A.

Canadian tributaries were not sampled during this study, it is not possible to calculate overall nutrient loadings to the reservoir.

The only known point source in Montana is the Eureka wastewater treatment plant which contributed an estimated 6.9% of the total phosphorus load ng originating in the U.S. portion of the drainage during the sampling year.

If the total phosphorus loading from the entire drainage basin during the sampling year is assumed to equal the phosphorus load leaving the reservoir, the reservoir received a loading amounting to about 90% of that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11). Undoubtedly this is a conservative estimate since the reservoir has a mean hydraulic retention time of 271 days and would be expected to retain from 40 to 60 percent of the incoming phosphorus load.

2. Non-point sources--It is estimated that non-point sources contributed about 93% of the phosphorus loading originating in the U.S. portion of the drainage basin during the sampling year. The Tobacco River added 47% of the total U.S. load.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 188.18 kilometers².

2. Mean depth: 38.4 meters.

3. Maximum depth: 109.4 meters.

4. Volume: 7,226.112 x $10^6$ $m^3$.

5. Mean hydraulic retention time: 271 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries (United States) -

| Name | | Drainage area ($km^2$)* | Mean flow ($m^3$/sec)* |
|---|---|---|---|
| Bristow Creek | | 66.8 | 0.44 |
| Big Creek | | 361.8 | 4.31 |
| Tobacco River | | 1,139.6 | 6.62 |
| Minor tributaries & immediate drainage (United States) - | | 1,461.7 | unknown |
| Totals | United States | 3,029.9 | unknown |
| | Canada | 20,053.0 | unknown |

2. Outlet -

| | | |
|---|---|---|
| Kootenai River | 23,271.1** | 308.61 |

C. Precipitation***:

1. Year of sampling: 45.5 centimeters.

2. Mean annual: 41.5 centimeters.

† Table of metric conversions--Appendix B.
†† Jones, 1975 (morphometry of entire reservoir); Bonde, 1976 (morphometry of U.S. portion).
* for limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

## III. WATER QUALITY SUMMARY

Keowanusa Reservoir was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at 5 or 6 stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, two 18.9-liter depth-integrated samples were composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 52.4 meters at station 1, 70.1 meters at station 2, 71.6 meters at station 3, 58.8 meters at station 4, 56.7 meters at station 5, and 44.5 meters at station 6.

The sampling results are presented in full in Appendix D and are summarized in the following table.

B. Biological characteristics:

1. Phytoplankton -

| Sampling Date | Dominant Genera | Algal Units per ml |
|---|---|---|
| 06/02/75 | 1. Carteria sp. | 339 |
| | 2. Pandorina sp. | 135 |
| | 3. Cryptomonas sp. | 135 |
| | 4. Centric diatoms | 135 |
| | 5. Nitzschia sp. | 68 |
| | Other genera | 35 |
| | Total | 847 |
| 07/24/75 | 1. Asterionella sp. | 355 |
| | 2. Chroomonas sp. | 148 |
| | 3. Cryptomonas sp. | 89 |
| | Total | 592 |
| 09/05/75 | 1. Chroomonas sp. | 124 |
| | 2. Anabaena sp. | 62 |
| | 3. Aphanizomenon sp. | 31 |
| | 4. Asterionella sp. | 31 |
| | Total | 248 |

2. Chlorophyll a -

| Sampling Date | Station Number | Chlorophyll a (ug/l) |
|---|---|---|
| 06/02/75 | 1 | 0.9 |
| | 2 | 2.0 |
| | 3 | 1.7 |
| | 4 | 2.5 |
| | 5 | 1.1 |
| | 6 | - |
| 07/24/75 | 1 | - |
| | 2 | 1.3 |
| | 3 | 4.3 |
| | 4 | 3.1 |
| | 5 | 1.9 |
| | 6 | 3.5 |
| 09/05/75 | 1 | 5.9 |
| | 2 | 5.6 |
| | 3 | 5.3 |
| | 4 | 1.7 |
| | 5 | 1.0 |
| | 6 | 1.0 |

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. Stations 1, 2, and 3 -

| Spike (mg/l) | Ortho P Conc. (mg/l) | Inorganic N Conc. (mg/l) | Maximum yield (mg/l-dry wt.) |
|---|---|---|---|
| Control | 0.040 | 0.080 | 4.4 |
| 0.050 P | 0.090 | 0.080 | 5.1 |
| 0.050 P + 1.0 N | 0.090 | 1.080 | 33.4 |
| 1.0 N | 0.040 | 1.080 | 16.9 |

b. Stations 4 and 5 -

| Spike (mg/l) | Ortho P Conc. (mg/l) | Inorganic N Conc. (mg/l) | Maximum yield (mg/l-dry wt.) |
|---|---|---|---|
| Control | 0.060 | 0.135 | 7.1 |
| 0.050 P | 0.110 | 0.135 | 7.5 |
| 0.050 P + 1.0 N | 0.110 | 1.135 | 28.4 |
| 1.0 N | 0.060 | 1.135 | 22.9 |

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Kooсanusa Reservoir was moderately high to high at the time the samples were collected (06/02/75). Also, significant increases in yields with the addition of nitrogen alone indicate the reservoir was nitrogen limited at that time.

The reservoir data also indicate nitrogen limitation; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 3/1 or less at all sampling times.

## IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples when possible from each of the U.S. tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the U.S. tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for the unsampled U.S. portion of the "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km²/year, at stations B-1 and C-1 and multiplying the means by the U.S. ZZ area in km².

The operator of the Eureka wastewater treatment plant provided monthly effluent samples and corresponding flow data; note, however, the flows appear to be estimated (see Appendix I).

A. Waste Sources:

1. Known municipal** .

| Name | Pop. Served | Treatment | Mean Flow ($m^3/d$) | Receiving Water |
|---|---|---|---|---|
| Eureka | 1,200 | prim. clari-fier | 1,135.6 | Tobacco River |

2. Known industrial - None

* See Working Paper No. 175.
** Treatment plant questionnaire.

B. Annual Total Phosphorus Loading (U.S. portion) - Average Year:

1. Inputs -

| Source | kg P/ yr | % of total |
|---|---|---|
| a. Tributaries (non-point load) - | | |
| Bristow Creek | 205 | 0.8 |
| Big Creek | 2,605 | 9.8 |
| Tobacco River | 12,590 | 47.3 |
| b. Minor tributaries & immediate drainage (non-point load) - | 7,310 | 27.5 |
| c. Known municipal STP's - | | |
| Eureka | 1,835 | 6.9 |
| d. Septic tanks* - None | - | - |
| e. Known industrial - None | - | - |
| f. Direct precipitation** - | 2,045 | 7.7 |
| Total | 26,590 | 100.0 |

2. Outputs -

Reservoir outlet - Kootenai River 228,840

3. Net annual P accumulation - Unknown.

* Hussman, 1976.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading (U.S. portion) - Average Year:

1. Inputs -

| Source | kg N/yr | % of total |
|---|---|---|
| a. Tributaries (non-point load) - | | |
| Bristow Creek | 5,100 | 1.2 |
| Big Creek | 29,170 | 7.0 |
| Tobacco River | 131,740 | 31.7 |
| b. Minor tributaries & immediate drainage (non-point load) - | 114,745 | 27.6 |
| c. Known municipal STP's - | | |
| Eureka | 9,120 | 2.2 |
| d. Septic tanks* - None | - | - |
| e. Known industrial - None | - | - |
| f. Direct precipitation** - | 126,095 | 30.3 |
| Total | 415,970 | 100.0 |

2. Outputs -

| | |
|---|---|
| Reservoir outlet - Kootenai River | 3,725,205 |

3. Net annual N accumulation - Unknown

D. Non-Point Nutrient Export by Subdrainage Area:

| Tributary | kg P/km²/yr | kg N/km²/yr |
|---|---|---|
| Bristow Creek | 3 | 76 |
| Big Creek | 7 | 81 |
| Tobacco River | 11 | 116 |

* Hussman, 1978.
** See Working Paper No. 175.

i. Mean Nutrient Concentrations in Ungaged Streams:

| Tributary | Mean Total P Conc. (mg/l) | Mean Total N Conc. (mg/l) |
|---|---|---|
| Pinkham Creek | 0.024 | 0.659 |
| Cripple Horse Creek | 0.017 | 0.567 |
| Canyon Creek | 0.031 | 0.734 |
| Jackson Creek | 0.018 | 0.336 |
| Barron Creek | 0.015 | 0.370 |
| Wartana Creek | 0.037 | 0.657 |
| McGuire Creek | 0.014 | 0.312 |

F. Yearly Loads:

In the following table, the phosphorus loadings that would exist if inputs equaled outputs are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

| | Total Phosphorus | | Total Nitrogen | |
|---|---|---|---|---|
| | Total | Accumulated | Total | Accumulated |
| grams/$m^2$/yr | 1.22* | ? | * | * |

Vollenweider phosphorus loadings (g/$m^2$/yr) based on mean depth and mean hydraulic retention time of Keocanusa Reservoir:

| | |
|---|---|
| "Dangerous" (eutrophic loading) | 1.36 |
| "Permissible" (oligotrophic loading) | 0.68 |

* Based on outlet load, assuming inlet load is at least equal to outlet load.

## V. LITERATURE REVIEWED

Bonde, Thomas, 1976. Personal communication (morphometric data). Libby Resident Office, U.S. Corps of Engineers, Libby, MT.

Bussman, Don, 1976. Personal communication (shoreline septic tanks). Supervisor's Office, Kootenai National Forest, Libby, MT.

Jones, R., 1975. Personal communication (morphometric data). U.S. Corps of Engineers, Seattle, WA.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

# VI. APPENDICES

## APPENDIX A

## LAKE RANKINGS

| | | |

APPENDIX B

CONVERSION FACTORS

## CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x $10^{-4}$ = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

# APPENDIX C

## TRIBUTARY FLOW DATA

# APPENDIX D

## PHYSICAL and CHEMICAL DATA

# APPENDIX E

## TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

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